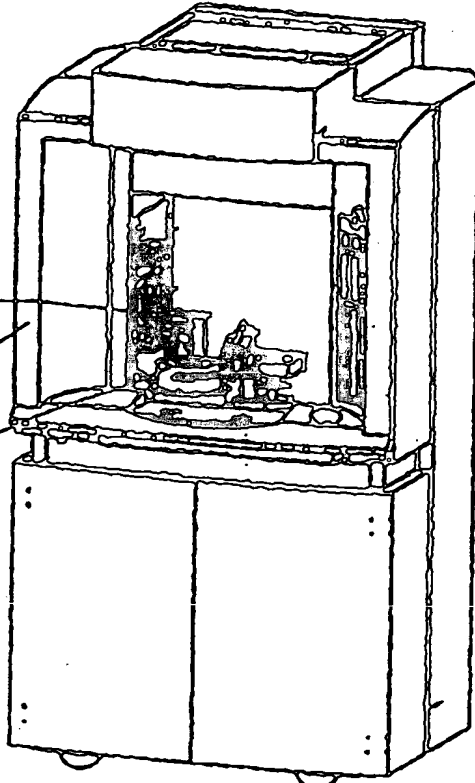


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<p>(54) Title: APPARATUS AND METHOD FOR COATING AND CURING AN OPTICAL ELEMENT WITH A UV PHOTSENSITIVE COATING</p>		
<p>(57) Abstract</p> <p>A coating and curing apparatus coats a top surface of a substrate with an uncured liquid coating and cures the uncured liquid coating in the same apparatus. The coating apparatus includes a coating station with a coating chamber with a top and a bottom, a rotatable substrate support member with a substrate support surface and a longitudinal axis extending from the coating station bottom. The substrate support surface is moveable along the longitudinal axis to advance the substrate in and out of the coating chamber through the coating chamber top. A substrate retainer device is configured to retain the substrate on the substrate support surface. A coating dispenser is coupled to a coating source and configured to apply the uncured liquid coating to the substrate top surface at the coating station. A curing station includes a curing chamber with a curing station support member configured to support the substrate. An electromagnetic energy source generates sufficient electromagnetic energy to convert the uncured liquid coating to a hard cured coating on the top surface of the substrate. A substrate transport device is configured to deliver the substrate to any of the stations. A housing is provided for the coating station and the curing station. The housing includes a gas flow device directing a gas flow at the coating station past the substrate support surface through the bottom of the coating chamber.</p>		
		

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APPARATUS AND METHOD FOR COATING AND CURING AN OPTICAL ELEMENT WITH A UV PHOTSENSITIVE COATING

BACKGROUND

5 Field of the Invention

This invention relates generally to an apparatus and method for applying a UV photosensitive coating to a substrate surface, and more particularly to an apparatus and method for applying and curing one or more photosensitive UV coatings to two optical elements in one apparatus that does not use solvents.

10

Description of the Related Art

Plastic materials have found increased usage for the construction of a variety of substrates, including but not limited to ophthalmic lenses for eyeglasses, cameras, and optical instruments, due to their light weight, ease of fabrication and relatively low cost. Common lens forming materials include CR-39 (diethyleneglycol bisallyl carbonate) available from PPG Industries, bisphenol A polycarbonate (PC), and poly(methylmethacrylate) (PMMA).

15

Plastic lens materials have traditionally possessed inferior resistance to scratching, commonly evaluated by rubbing the surface with steel wool; and inferior resistance to abrasion, usually measured by shaking the lens surface under a bed of sand in the Bayer Abrasion Test. The cumulative effect of scratching and abrading the lens surface is to increase the haze in the lens and ultimately to produce a substantially translucent lens incapable of providing a coherent image.

20

Lens manufacturers have developed thin proprietary coatings which protect the plastic lens from scratching in normal use and that can also provide tinting of the lens. These coatings are typically photosensitive to UV radiation

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30

and can be cured to a hardened state by exposure to the proper wavelengths for a sufficient time.

5 An apparatus for curing photosensitive coatings for ophthalmic lenses has been disclosed in U.S. Patent No. 5,097,136 (hereafter the " '136 patent"). In the '136 patent, the UV curable coating is first applied to the lens in a first apparatus. It is then transferred to a second apparatus which only performs the curing function by exposure to UV radiation. Thus, the two functions of applying the UV curable coating and supplying UV radiation to actually cure the applied material are performed in two separate devices. The apparatus disclosed
10 in the '136 patent cures only one lens at a time, fails to minimize hazardous waste and uses solvents.

Other patents which disclose apparatus for UV curing of materials are found in U.S. Patent No. 3,826,014 and U.S. Patent No. 3,950,650.

15 It would be desirable to provide an apparatus that applies and cures a photosensitive coating on a substrate surface in a single device. It would be further desirable to apply and cure a UV photosensitive coating in a single device with coating materials that use substantially no solvents.

SUMMARY OF THE INVENTION

20 Accordingly, an object of the invention is to provide a method and apparatus for applying and curing at least one UV photosensitive coating to one or more substrate surfaces, such as a lens, in a single device.

25 Another object of the invention is to provide a method and apparatus for applying and curing at least one UV photosensitive coating to one or more optical elements in a single device in a substantially solvent free system.

30 Still a further object of the invention is to provide a method and apparatus for applying and curing at least one UV photosensitive coating to one or more optical elements in a single device where at least 75% of excess coating is collected and cured simultaneously as the coating is applied to the optical element.

Yet another object of the invention is to provide a method and apparatus for applying and curing at least one UV photosensitive coating to one or more optical elements in a single device that provides a laminar flow around a top surface of the optical elements.

5 Another object of the invention is to provide a method and apparatus for applying and curing a UV photosensitive tinting coating to an optical element.

 Still another object of the invention is to provide a method and apparatus for applying a compliant abrasion enhancement UV photosensitive coating to at least one surface of an optical element, and thereafter, a scratch and abrasion
10 resistant UV photosensitive coating on the compliant abrasion enhancement coating, and then curing both coatings, all in a single device.

 These and other objects of the invention are achieved in an apparatus for coating a top surface of a substrate with an uncured liquid coating and curing the uncured liquid coating. The coating apparatus includes a coating station with
15 a coating chamber with a top and a bottom, a rotatable substrate support member with a substrate support surface and a longitudinal axis extending from the coating station bottom. The substrate support surface is moveable along the longitudinal axis to advance the substrate in and out of the coating chamber through the coating chamber top. A substrate retainer device is configured to
20 retain the substrate on the substrate support surface. A coating dispenser is coupled to a coating source and configured to apply the uncured liquid coating to the substrate top surface at the coating station. A curing station includes a curing chamber with a curing station support member configured to support the substrate. An electromagnetic energy source generates sufficient
25 electromagnetic energy to convert the uncured liquid coating to a hard cured coating on the top surface of the substrate. A substrate transport device is configured to deliver the substrate to any of the stations. A housing is provided for the coating station and the curing station. The housing includes a gas flow device directing a gas flow at the coating station past the substrate support
30 surface through the bottom of the coating chamber.

The present invention provides a method for coating and curing a photosensitive coating on a substrate. A housing is provided that includes a coating station with a substrate support, a coating dispenser, a curing station with a substrate support, and a substrate transport device. The substrate is positioned at the coating station. A laminar exhaust flow directs a gas flow away from a top surface of the substrate. A photosensitive coating is applied to the top surface of the substrate. The substrate is spun with the photosensitive coating applied to the top surface of the substrate until a desired coating thickness is formed. At least 75% of an excess of photosensitive coating, that does not remain on the top surface of the optical element, is collected at the coating station. The substrate is moved to the curing station. Sufficient energy is supplied to the substrate to cure the coating on the top surface of the substrate. A coated substrate is removed from the housing.

In one embodiment, the substrate is an optical element such as an optical lens. The gas flow device is a laminar flow device configured to provide a vertical gas flow. The gas flow device pulls gas around edges of the substrate positioned on the substrate support surface, and minimizes deposition of particles with sizes of 0.3 microns or larger on the substrate top surface. The substrate support surface is configured to rotate at speeds of about 10 to 10,000 RPM. The coating chamber may include a splash cup to capture at 75% of an excess of a coating applied to the top surface of the substrate.

The coating station can include a second coating chamber. A second coating dispenser is coupled to a second coating source and configured to apply a second coating to the first coating on the substrate top surface.

In one specific embodiment, a pair of ophthalmic lenses are each coated with first coating comprising an abrasion enhancement coating. The first coating is then cured. A second coating comprising a scratch and abrasion resistant coating is then applied on top of the first coating. The second coating is cured, and the two lenses are removed from the apparatus. Optionally, the scratch and abrasion resistant layer can also be a tinting layer.

DESCRIPTION OF THE DRAWINGS

Figure 1 is a perspective view of the coating and curing apparatus of the present invention.

5 Figure 2 is a perspective view of the coating station of the apparatus of Figure 1.

Figure 3 is a perspective view of the coating station, coating dispenser and lens transport device of the apparatus of Figure 1.

10 Figure 4 is a perspective view of the curing station of the apparatus of Figure 1.

Figure 5 is a perspective view of the coating dispenser of Figure 1.

Figure 6 is a perspective view of the substrate transport device of Figure 1.

15 DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to Figures 1 through 6, a coating and curing apparatus 10 provides coating a top surface of a substrate with an uncured liquid coating, and curing the uncured liquid coating. The coating and curing procedures are performed in apparatus 10.

20 Apparatus 10 includes a coating station 12. Coating station 12 has, (i) a coating chamber 14 with a top 16 and a bottom 18, and (ii) a rotatable substrate support member 20 with a substrate support surface 22 and a longitudinal axis 24 extending from coating station bottom 18. Substrate support surface 22 is moveable along longitudinal axis 24 to advance a substrate 26 in and out of
25 coating chamber 14 through coating chamber top 16.

Substrate 26 can be a variety of different devices but is preferably an optical element such as a lens. Suitable lenses can be single vision, bifocal, trifocal or progressive multifocal. For purposes of this disclosure, substrate 26 will hereafter be referred to as "lens 26", and the term "substrate" will be referred
30 to as "lens".

A lens retainer device 28 is configured to retain lens 26 on lens support surface 22. Lens support surface 22 is configured to rotate at a speed of about 10 to 10,000 RPM, and in one embodiment at a speed of about 2,000 to 4,000 RPM.

5 In one embodiment, lens retainer device 28 is a vacuum chuck coupled to a vacuum source. After a lens 26 is positioned on vacuum chuck 28, vacuum chuck 28 is retracted into an interior of a resin collector 30. As resin is spin coated on lens 26, excess resin is collected in resin collector 30 for later processing and removal. The excess resin is cured at a curing station 32 and is
10 later removed. In one embodiment, resin collector 30 collects 75% or more of excess resin that does not remain on a lens top surface 34 during spin coating.

Coating station 12 further includes two or more rails 36 housing linear bearings, a pneumatic air cylinder 38 that advances and retracts vacuum chuck 28 in and out of the interior of resin collector 30, a motor 40 coupled to vacuum
15 chuck 28 and a support frame 42.

A coating dispenser 44 is coupled to a coating source 46 and configured to apply an uncured liquid coating to a lens top surface 34 at coating station 12. Lens top surface 34 can be curved. When lens top surface 34 is curved it creates turbulence when rotated on lens support surface 22. Coating dispenser
20 30 includes a valve. A stepper motor 46 is coupled to the valve. Stepper motor 46 advances and retracts valve. Lens centering pins 48 provide positioning of lens 26.

Curing station 36 includes a curing chamber 50 with a curing station support member 52 configured to provide support for lens 26. An
25 electromagnetic energy source 54, positioned at curing station 36, generates sufficient electromagnetic energy to convert the uncured liquid coating to a hard cured coating on lens top surface 34. A variety of electromagnetic energy sources 54 can be used, including but not limited to an actinic UV light source, such as a lamp with and without a shutter, and the like. A sub-housing,
30 positioned at curing station 32, has a gas inlet flow device for introducing a variety of different gases. Preferably, an inert gas is introduced.

A second coating chamber may also be provided to apply a different coating material to lens 26 or to increase throughput. The second coating chamber includes substantially the same components as coating chamber 14. Also included is a second coating dispenser.

5 A lens transport device 56 is configured to deliver lens 26 to any of the stations 12 or 32. As illustrated in Figure 5, an air cylinder 58 is coupled to a cleaning nozzle 60 at lens transport device 56. Lens transport device 56 includes a lens support 60 which supports lens 26 as it is moved from station to station, and a curing transfer station 62 that lifts lens 26 off lens support 62.

10 A housing 64 provides an enclosure for coating station 12 and curing station 32. The temperature within housing 64 is maintained from 75 to 100 degrees F, and more preferably between 85 and 90 degrees F. The amount of oxygen at curing station 36 is controlled to 20% more less, and preferably 1% or less. Housing 64 includes a gas flow device 66 directing a gas flow at coating
15 station 12.

 A laminar gas flow is generated above and around lens support surface 22. In one embodiment, the laminar gas flow is sufficient to minimize deposition of particles with sizes of 0.3 microns or larger on lens top surface 34. Exhaust is pulled around and below lens 26 through coating station bottom 18 when lens
20 26 is positioned on lens support surface 22.

 In one embodiment, a first coating is an abrasion enhancement coating. After application of the first coating at coating chamber 14, lens 26 is then transported by lens transport device 56 to curing station 32 where it is cured. Lens 26 is then removed from curing station 32 by lens transport device 56 and
25 moved to back to coating chamber where a second coating is applied by the second coating dispenser. A second coating, which may be a scratch and abrasion resistant coating, is then applied on top of the first coating. Lens 26 is moved from coating station 14 by lens transport device 56 to curing station 32. After curing, lens 26 is removed from curing station 32 and from housing 64.

30 The abrasion enhancement layer has a number of desirable properties:

1. It adheres well to both the lens and the top coating and provides a substantial durable bond.

2. Abrasion enhancement layer is compliant to the top coating layer and is a "soft" material with a lower modulus than the harder top coating layer. The general physical characteristics of the abrasion enhancement layer are those of a compliant material. A degree of cross-linking is desirable for the performance of the abrasion enhancement layer, including resistance to creep.

3. Abrasion enhancement layer can be solvent-borne, but is preferably a solvent free (100% solids system) that can be applied as a liquid, such as by spray or spin coating techniques, and is convertible to its desired final physical state by exposure to an energy source, preferably ultraviolet actinic radiation, although thermal curing to the desired final physical state is possible. Free radical based curing regimens are preferred, but cationic or catalyzed curing systems can be used.

4. Abrasion enhancement layer is resistant to environmental degradation, including but not limited to exposure to temperature, humidity or sunlight, and is also durable. The operational temperature range is at least 20 degrees C to 50 degrees C.

Without being bound by any specific explanation for the observed benefit effects of the abrasion enhancement layer, it is believed that the abrasion enhancement layer allows the deformation of the top coating layer when it is contacted by rough objects. This deformation allows the transfer of the frictional and impact energy from the top coating to the abrasion enhancement layer where it can be absorbed and dissipated. The top coating layer, which is innately more brittle than the abrasion enhancement layer, does not reach the critical tensional and compressional threshold where cracks can form that scatter light, and give a hazy appearance. While the steel wool resistance of a coating is believed to be mostly related to the hardness of the coating, the Bayer abrasion resistance is believed to be more related to the ability of a coating to endure impact without chipping or cracking. Additionally, a single coating layer is tightly bonded directly to the lens surface and a considerable internal stress remains in the

coating after curing, particularly in the x and y directions. With the present invention, the abrasion enhancement layer is bonded to lens top surface 34. Residual stress in the top coating layer from that curing process is reduced or eliminated altogether. The top coating layer becomes more notch insensitive relative to the traditional single coating layer approach.

In one embodiment, the abrasion enhancement layer has a modulus of M_1 and a Shore A value of 50 or less. The top coating layer is deposited on the abrasion enhancement layer. The top coating layer has a modulus, M_2 , where M_2 is greater than M_1 , and an abrasion resistance Bayer haze gain ratio of 1.0 or greater. The top coating layer has a Shore D value of 50 or higher, and a steel wool % haze gain of 10 or lower. The thicknesses of the abrasion enhancement layer and the top coating layer can vary and be independent. Preferable thicknesses are 2-50 microns, more preferably 5-20 microns for each layer.

The abrasion enhancement layer can have the following composition:

I. Thirty to ninety five parts of a flexible acrylated oligomer or acrylated oligomer/acrylate monomer blend resin (A);

II. Five to seventy parts of a mono vinyl functional reactive diluent (RD);

III. Optionally, five to thirty parts of alkane polyols, wherein the alkane polyols contain up to about twenty four carbons atoms and an average of at least two O-acryloyl groups (AE);

IV. Optionally, five to thirty parts of alkane polyols, wherein the alkane polyols contain up to about forty eight carbon atoms and average at least three O-[acryloyl-(polyalkylene oxide)] chains; wherein each of the polyalkylene oxide chains comprise from one to twenty alkaline oxide groups (AOA);

V. Optionally, fifteen to seventy five parts of polyacrylated urethane, wherein the urethane oligomer has a molecular weight of about 2500 or less and an average of at least two acrylate groups (UA); and

VI. Optionally, one tenth to fifteen parts of a non-vinyl functional plasticizer (P), such that the cured abrasion enhancing layer is softer than the cured top coat layer

This composition can also contain a photoinitiating amount of a photoinitiator, typically one tenth to about ten parts, as well as optional surfactants and stabilizers.

5 Additionally, the abrasion enhancement layer can have the following composition:

- I. Thirty to eighty parts of a flexible acrylated oligomer or acrylated oligomer/acrylate monomer blend resin (A); and
- II. Twenty to seventy parts of a mono vinyl functional reactive diluent (RD).

10 The top coating layer can have the following composition:

- I. Twenty to seventy parts of alkane polyols, wherein the alkane polyols contain up to about forty eight carbon atoms and average at least three O-[acryloyl-(polyalkylene oxide)] chains; where in each of the polyalkylene oxide chains comprise from one to twenty alkylene oxide groups (AOA);

- 15 II. Fifteen to seventy five parts of a polyacrylated urethane, wherein the urethane oligomer has a molecular weight of about 2500 or less and average of at least two acrylate groups (UA);

- III. Optionally, twenty to seventy parts of polyacryloylated alkane polyols, wherein the alkane polyols contain up to twenty four carbon atoms and an average of at least three O-acryloyl groups (AE); and

- 20 IV. Optionally, one to twenty five parts of a mono vinyl functional reactive diluent (RD).

The top coating composition can also contain a photoinitiating amount of photoinitiator, typically one tenth to about ten parts, as well as optional surfactants and stabilizers.

25 Another class of a scratch and abrasion-resistant, radiation curable or heat curable coating composition used in accordance with the present invention comprises:

- I. Ten to fifty parts of polyacryloylated alkane polyols, wherein the alkane polyols contain up to about twenty four carbon atoms and an average of at least three O-acryloyl groups (AE); and

II. Twenty to eighty parts of alkane polyols, wherein the alkane polyols contain up to about forty eight carbon atoms and average at least three O-[acryloyl-(polyalkylene oxide)] chains; wherein each of the polyalkylene oxide chains comprise from one to twenty alkylene oxide groups (AOA).

5 This composition will also contain a photoinitiating amount of a photoinitiator, typically one tenth to about ten parts, as well as optional surfactants and stabilizers.

COMMERCIAL EXAMPLES OF COMPOSITION COMPONENTS

"A" (FLEXIBLE ACRYLATED OLIGOMER OR OLIGOMER/MONOMER BLEND RESIN MATERIAL) EXAMPLES

10 Examples of suitable flexible oligomer or oligomer/monomer blend materials are Sartomer CN 300; Radcure Ebecryl 3600, Ebecryl 3703, Ebecryl 270, Ebecryl 4830, Ebecryl 4834, Ebecryl 4881, Ebecryl 4883, Ebecryl 8402, Ebecryl 525, Ebecryl 585, Ebecryl 745, Ebecryl 754, Ebecryl 767, Ebecryl 1755; Henkel Photomer 6230; DSM Desotech 3471-1-135.

"RD" (REACTIVE DILUENTS) EXAMPLES

20 Examples of suitable mono vinyl functional reactive diluents are Sartomer SR 203, SR 232, SR 244, SR 256, SR 339, SR 395, SR 440, SR 493, SR 506, Radcure IBOA, Radcure ODA, Radcure B-CEA; Henkel Photomer 4039, Photomer 4842, Photomer 4816, Photomer 4822, Photomer 8061 and Photomer 8127.

"AE" (ACRYLATE ESTER) EXAMPLES FOR ABRASION ENHANCEMENT LAYER 42:

25 Examples of suitable two functional acrylated aliphatic polyol esters are Sartomer SR 205, SR 209, SR 210, SR 230, SR 231, SR 252, SR 259, SR 268, SR 272, SR 306, SR 344, SR 9003, SR 9209; Radcure TRPGDA, Radcure HDODA; Henkel Photomer 4050, Photomer 4065, Photomer 4061, Photomer

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4126, Photomer 4127, Photomer 4160, Photomer 4193, and Photomer 4204.

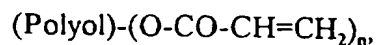
Examples of three or greater functional acrylated aliphatic polyol ester are

Sartomer SR 350, SR 351, SR 444, SR 295, SR 335, SR 399, SR 9041;

Radcure DHPA, Radcure PETA K, Radcure TMPTA; Henkel Photomer 4006,

Photomer 4335, and Photomer 4399.

A general chemical structure may be written:



where $n \geq 2$

10 "AOA" EXAMPLES

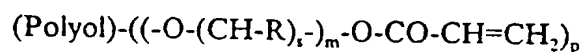
Examples of alkoxyated acrylates are Sartomer SR 415, SR 454, SR

492, SR 499, SR 502, SR 9035; Radcure OTA-480, Radcure TMPTEOA;

Radcure Ebecryl 53; Henkel Photomer 4072, Photomer 4094, Photomer 4095,

Photomer 4149, Photomer 4155, Photomer 4158, and Photomer 4355.

15 A general chemical structure may be written:



where $p \geq 3$

$m = 1-20$

$s = 1-6$

20 R is H or lower alkyl, preferable H or methyl

"UA" (ACRYLATED URETHANE) EXAMPLES

Examples of urethane acrylates are Sartomer CN 953, CN 961, CN 963,

CN 964, CN 970, CN 971, CN 972, CN 975, CN 980; Radcure Ebecryl 8804,

25 Ebecryl 220, Ebecryl 6602, Henkel Photomer 6210, Photomer 6008, Photomer 6010.

"P" (PLASTICIZER) EXAMPLES

Examples of plasticizers are the aliphatic or aralkyl esters of aromatic

30 acids, diacids, and triacids, (such as benzoic, phthalic, isophthalic, terephthalic,

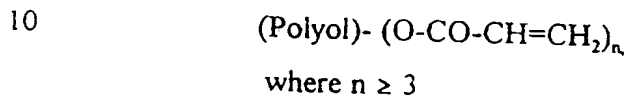
and trimellitic acids) such as dioctyl phthalate (DOP) and dibenzyl phthalate; the

aliphatic or aralkyl esters of aliphatic acids (such as adipic, azelaic, glutaric, and citric acids) such as dioctyl adipate; and phosphate esters.

"AE" (ACRYLATE ESTER) EXAMPLES FOR TOP COATING LAYER 44

5 Examples of acrylated aliphatic polyol ester which average three or greater acrylic functionality are Sartomer SR 350, SR 351, SR 444, SR 295, SR 355, SR 399, SR 9041; Radcure DPHPA, Radcure PETA K, Radcure TMPTA; Henkel Photomer 4006, Photomer 4355, and 4399.

A general chemical structure may be written:



15

TEST METHOD DESCRIPTION

BAYER ABRASION RESISTANCE

20 A Bayer Sand Abrasion Tester is used for the determination of surface abrasion resistance. The sample, dual coated with abrasion enhancing layer and top coat, along with a control sample of CR-39 is cleaned with mild soapy water, rinse with water, then air dried. The light transmission of the both at 550 nm is determined using a Fisher UV-VIS Spectrophotometer (reference ASTM D 1003-61 "Standard Test Method for Measuring Haze and Luminous

25 Transmittance of Transparent Plastics"). The cleaned sample is mounted to cover one of the holes in the underside of the testing pan. The control sample of uncoated CR-39 is place under the other hole, then 1.0 kilograms of new sand, which has been sieved to retain the portion passing a #7 but held by a #14 sieve, is placed in the pan. The sand filled pan is shaken over a 4 inch stroke at a rate

30 of sieve, is placed in the pan. The sand filled pan is shaken over a 4 inch stroke at a rate of 150 cycles per minute for a total of 300 cycles. Both sample and

control are cleaned with mild soapy water, rinsed with water, then air dried. The light transmission of the both at 550 nm is determined. The percent haze gain due to abrading the sample surfaces with sand is calculated; the Bayer Haze Gain Ratio is determined by dividing the measured haze gain for the CR-39 control by that of the sample under evaluation. By definition, the Bayer Haze Gain Ratio for CR-39 is 1.0.

SCRATCH RESISTANCE

10 An Eberbach 6000 Steel Wool Abrasion Tester is used for the determination of surface scratch resistance. A piece of 000 steel wool (Pro's Best, International Steel Wool Co.) is mounted over the end of a one inch by one inch mandrel with the steel wool strands aligned in the direction of motion. The sample, dual coated with abrasion enhancing layer and top coat layer, is cleaned with mild soapy water, rinsed with water, then air dried. The light transmission of the sample at 550 nm is determined using a Fisher UV-VIS Spectrophotometer (reference ASTM D 1003-61 "Standard Test Method for Measuring Haze and Luminous Transmittance of Transparent Plastics"). The cleaned sample is mounted onto the testing stage, then the mandrel set in place and weighted with 32 pounds. Twenty complete cycles back and forth across the sample are applied at a rate of 100 cycles per minute. The sample is re-cleaned with mild soapy water, rinsed with water, then air dried and the light transmission of the sample at 550 nm is determined. The percent hazed gain due to scratching the sample surface with steel wool is calculated by comparison with the value before testing and reported.

CROSS-HATCH TAPE PEEL ADHESION TEST

30 A sample plastic lens is coated and cured with the abrasion enhancing layer and topcoat layer under evaluation. A cross-hatched grid of twenty five squares 2 mm on a side is scored through both layers down to the lens using a razor knife. One end of a three inch by three fourths inch piece of Scotch Tape

#600 ® (3M Co.) is placed over the grid and pressed to bond uniformly to the topcoat surface. The tape is folded back then peeled off the surface with a rapid hand motion. If no more than one square of the grid is found to have debonded from the lens and adhered to the tape, the sample configuration is deemed to have passed the adhesion test. If no more than one square debonds, the sample is deemed to have failed the adhesion test. Reference is made to test ASTM D-3359.

HARDNESS EVALUATION OF CURED AEL AND TOPCOAT COMPOSITIONS

The relative hardness of cured AEL and topcoat compositions on the Shore A and /or Shore D scales was determined using a durometer. The neat resin sample was poured into a 1"x 1"x 1/8" mold cavity formed by a PVC gasket held between two quartz plates. The sample was cured using a Fusion System H Bulb with an exposure time of about 8-12 seconds. Cured samples were removed from the mold, allowed to cool to ambient temperature, then the hardness on the Shore A or D scale determined with the respective Shore Durometer. There is some overlap in the scales, but the A scale can assess the hardness of softer samples, while the D scale is used for relatively harder samples.

DESCRIPTION OF EXAMPLE SAMPLE PREPARATION

SPIN COATING AND UV CURING

A lens sample, about 3 inches in diameter and 1/8 inch thick, is mounted on the spin table of the spin coating apparatus. While spinning at about 150 rpm, the sample surface is washed with isopropyl alcohol, then the speed increased to 2000-3000 rpm and held until sample surface is dry, about 30-60 seconds. While spinning at about 150 rpm, the abrasion enhancing layer (AEL) is applied with a pipette to the lens surface, working from the center to the edge of the sample, to form a uniform coating layer. The spin speed is then increased to the range

1000-6000 rpm and held for 15-90 seconds until the desired layer thickness is achieved, generally in the range of 1-50 microns. The wet coated lens is placed in an enclosed chamber with a quartz window, nitrogen purged through the cavity, then the chamber with sample is passed on a conveyor belt under a Fusion systems UV Lamp to cure the abrasion enhancing layer. Total irradiation time for AEL is 1-10 seconds. The coated sample is returned to the spin table, then the topcoat is applied by pipette across the slowly spinning AEL sample surface. The spin speed is then increased to the range 1000-6000 rpm and held for 15-90 seconds until the desired layer thickness is achieved, generally in the range of 1-50 microns. The wet coated AEL/lens is placed in the chamber with a quartz window, nitrogen purged through the cavity, then the chamber passed on a conveyor belt under a Fusion Systems UC Lamp to cure the topcoat layer. Total irradiation time for the top coat layer is 1-10 seconds.

What is claimed is:

1. An apparatus for coating a top surface of a substrate with an uncured liquid coating and curing the uncured liquid coating, comprising:
 - a coating station including a coating chamber with a top and a bottom, a rotatable substrate support member with a substrate support surface and a longitudinal axis extending from the coating station bottom, the substrate support surface being moveable along the longitudinal axis to advance the substrate in and out of the coating chamber through the coating chamber top, and a substrate retainer device configured to retain the substrate on the substrate support surface;
 - a coating dispenser coupled to a coating source and configured to apply the uncured liquid coating to the substrate top surface at the coating station;
 - a curing station including a curing chamber with a curing station support member configured to support the substrate, and an electromagnetic energy source generating sufficient electromagnetic energy to convert the uncured liquid coating to a hard cured coating on the top surface of the substrate;
 - a substrate transport device configured to deliver the substrate to any of the stations; and
 - a housing for the coating station and the curing station, the housing including a gas flow device directing a gas flow at the coating station past the substrate support surface through the bottom of the coating chamber.
2. The apparatus of claim 1, further comprising:
 - a sub-housing positioned at the curing station including an inert gas flow device that directs inert gas into the curing chamber.
3. The apparatus of claim 1, further comprising:
 - a spray nozzle positioned at the coating station.
4. The apparatus of claim 3, wherein the spray nozzle applies an atomized mixture of air and an aqueous cleaning solution to clean the substrate.

5. The apparatus of claim 1, wherein the gas flow device is a laminar flow device configured to provide a vertical gas flow in a direction towards a top surface of the substrate.

6. The apparatus of claim 1, further comprising:
an exhaust flow device positioned in the coating chamber and configured to provide an exhaust flow in the coating chamber in a selected direction.

7. The apparatus of claim 1, further comprising:
an inert gas flow device positioned in the curing chamber and configured to provide an inert gas flow.

8. The apparatus of claim 1, wherein the gas flow device pulls gas around an edges of a substrate positioned on the substrate support surface through the bottom of the coating chamber.

9. The apparatus of claim 1, wherein the substrate has a curved top surface.

10. The apparatus of claim 1, wherein the curved top surface creates turbulence when rotated on the substrate support surface.

11. The apparatus of claim 1, wherein the substrate support surface is configured to rotate at a speed of about 10 to 10,000 RPM.

12. The apparatus of claim 1, wherein the substrate support surface is configured to rotate at a speed of about 2,000 to 4,000 RPM.

13. The apparatus of claim 1, wherein the substrate is an optical lens.

14. The apparatus of claim 1, wherein the gas flow device provides sufficient flow to minimize a deposition of particles with sizes of 0.3 microns or larger on the substrate top surface.
15. The apparatus of claim 1, wherein the electromagnetic energy source is an actinic UV light source.
16. The apparatus of claim 15, wherein the actinic UV light source is a lamp.
17. The apparatus of claim 15, wherein the actinic UV light source is a lamp with a shutter.
18. The apparatus of claim 1, wherein the coating chamber includes a splash cup to capture at least 75% of an excess of a coating applied to the top surface of the substrate.
19. The apparatus of claim 18, wherein the coating chamber includes a member for removing the excess of the coating.
20. The apparatus of claim 1, wherein the substrate retainer device includes a vacuum source.
21. The apparatus of claim 1, wherein the coating station is configured to provide cleaning of the substrate.
22. The apparatus of claim 1, wherein the coating station includes a second coating chamber.

23. The apparatus of claim 1, further comprising:
a second coating dispenser coupled to a second coating source and configured to apply a second coating to the first coating on the substrate top surface.
24. The apparatus of claim 1, wherein the coating station is configured to center a lens on a spindle in the coating station.
25. The apparatus of claim 1, wherein the coating station includes a balancing mechanism suitable for asymmetric lenses.
26. The apparatus of claim 1, wherein a temperature in the housing is maintained from 75 to 100 degrees F.
27. The apparatus of claim 1, wherein a temperature in the housing is maintained from 85 to 90 degrees F.
28. The apparatus of claim 1, wherein the coating station is configured to support one of a lens selected from a single vision, bifocal, trifocal or progressive multifocal.
29. The apparatus of claim 1, wherein the coating dispenser is configured to provide a controlled dispersion location on the substrate.
30. The apparatus of claim 1, wherein the a controlled oxygen environment of 0 to 20% is provided in the curing chamber.
31. The apparatus of claim 1, wherein a controlled oxygen environment of 0 to 1% is provided in the curing chamber.

32. The apparatus of claim 1, wherein the coating chamber captures an excess of coating material spun off from a rotated coated substrate.

33. A method for coating and curing a photosensitive coating on a substrate, comprising:

providing a housing including a coating station with a substrate support, a coating dispenser, a curing station with a substrate support, and a substrate transport device;

positioning the substrate at the coating station;

introducing a laminar flow to direct a gas flow away from a top surface of the substrate;

apply a photosensitive coating to the top surface of the substrate;

spinning the substrate with the photosensitive coating applied to the top surface of the substrate until a desired coating thickness is formed;

collecting at least 75% of an excess of photosensitive coating, that does not remain on the top surface of the optical element, at the coating station;

moving the substrate to the curing station;

supplying sufficient energy to the substrate to cure the coating on the top surface of the substrate; and

removing a coated substrate from the housing.

34. The method of claim 33, wherein the laminar flow directs gas away the top surface of the substrate.

35. The method of claim 33, wherein an exhaust flow pulls gas around an edges of a substrate positioned on the substrate support surface through the bottom of the coating chamber.

36. The method of claim 33, wherein the coating is spin coated on the substrate top surface.

37. The method of claim 33, wherein the coating is UV photosensitive.
38. The method of claim 33, wherein a second coating is applied to the top of the substrate.
39. The method of claim 38, wherein the second coating is applied after a first coating is cured.
40. The method of claim 39, wherein the second coating is cured after it has been applied to the substrate.
41. The method of claim 40, wherein the substrate is removed from the housing after the second coating is cured.
42. The method of claim 33, wherein the laminar flow provides sufficient flow to minimize a deposition of particles with sizes of 0.3 microns or larger on the substrate top surface.
43. The method of claim 33, wherein the substrate is spun at a speed of 1 to 100 radians/sec.
44. The method of claim 33, wherein a coating viscosity of the coating is 0.05 to 100 poise.
45. The method of claim 33, wherein the substrate is spun from 1 to 600 seconds.
46. The method of claim 33, wherein a coating density is 0.85 to 1.5 g/ml.

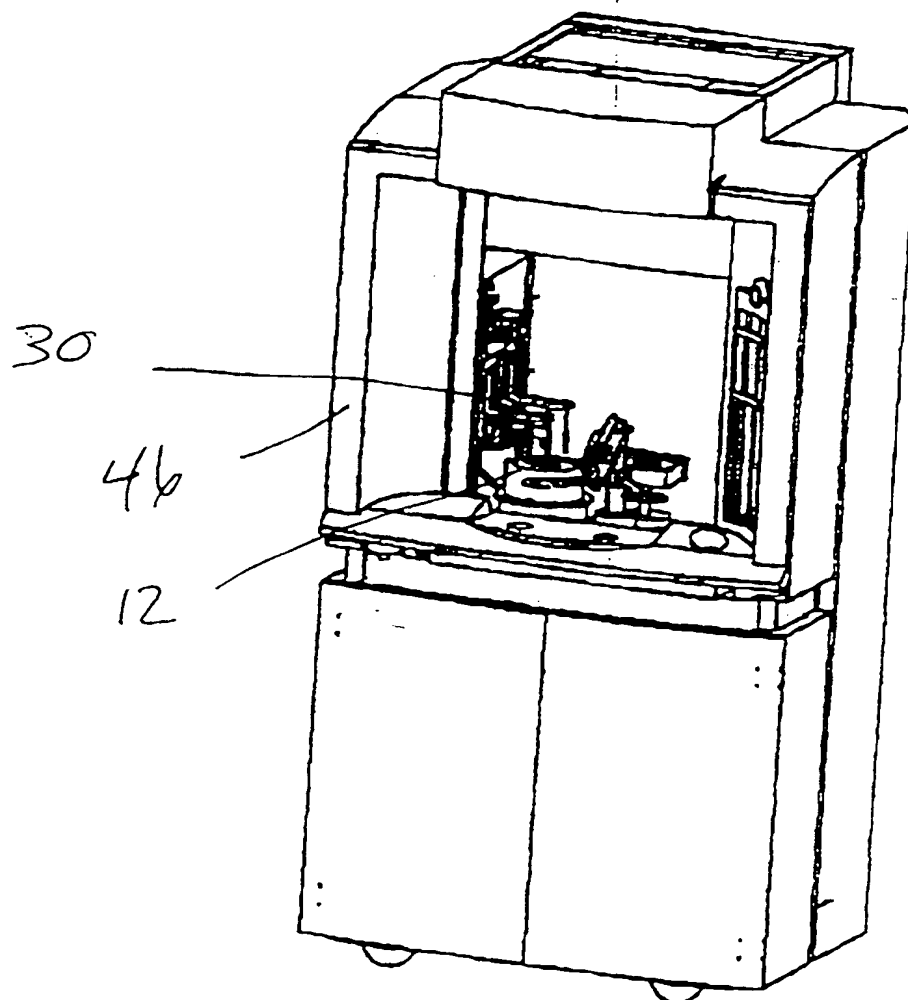
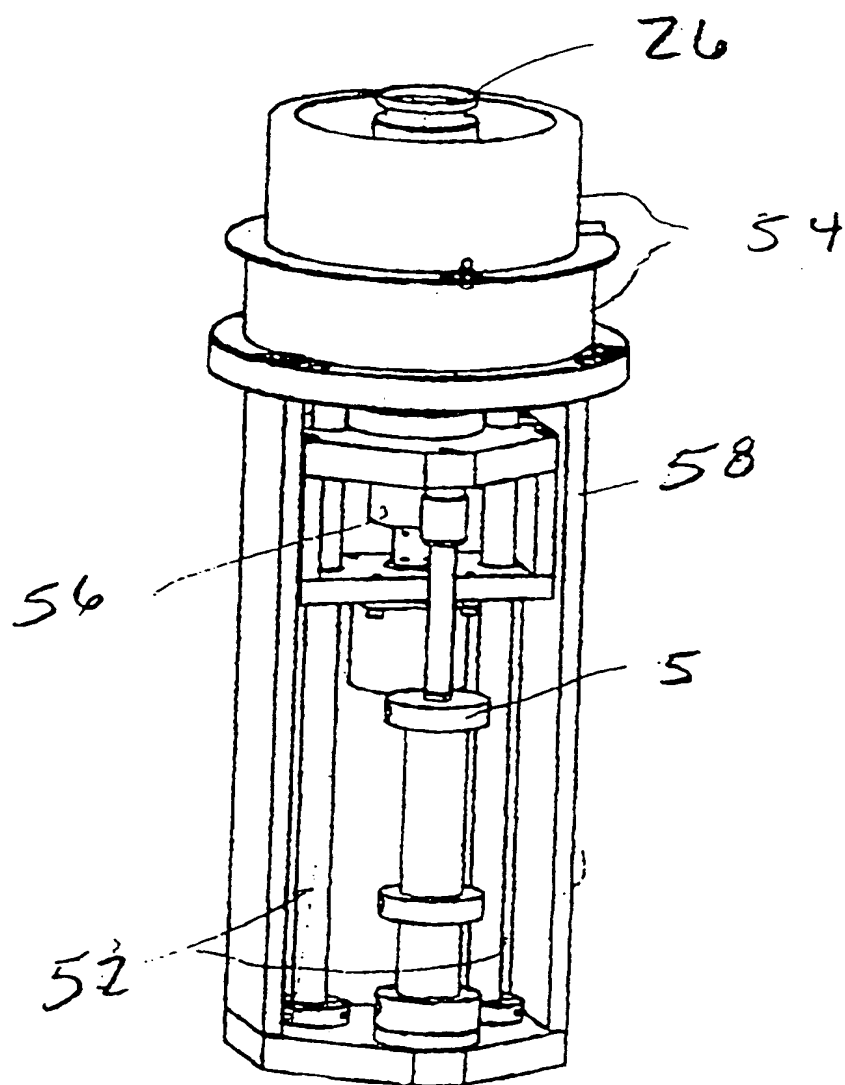


Fig 1



Coating Station

Fig 2

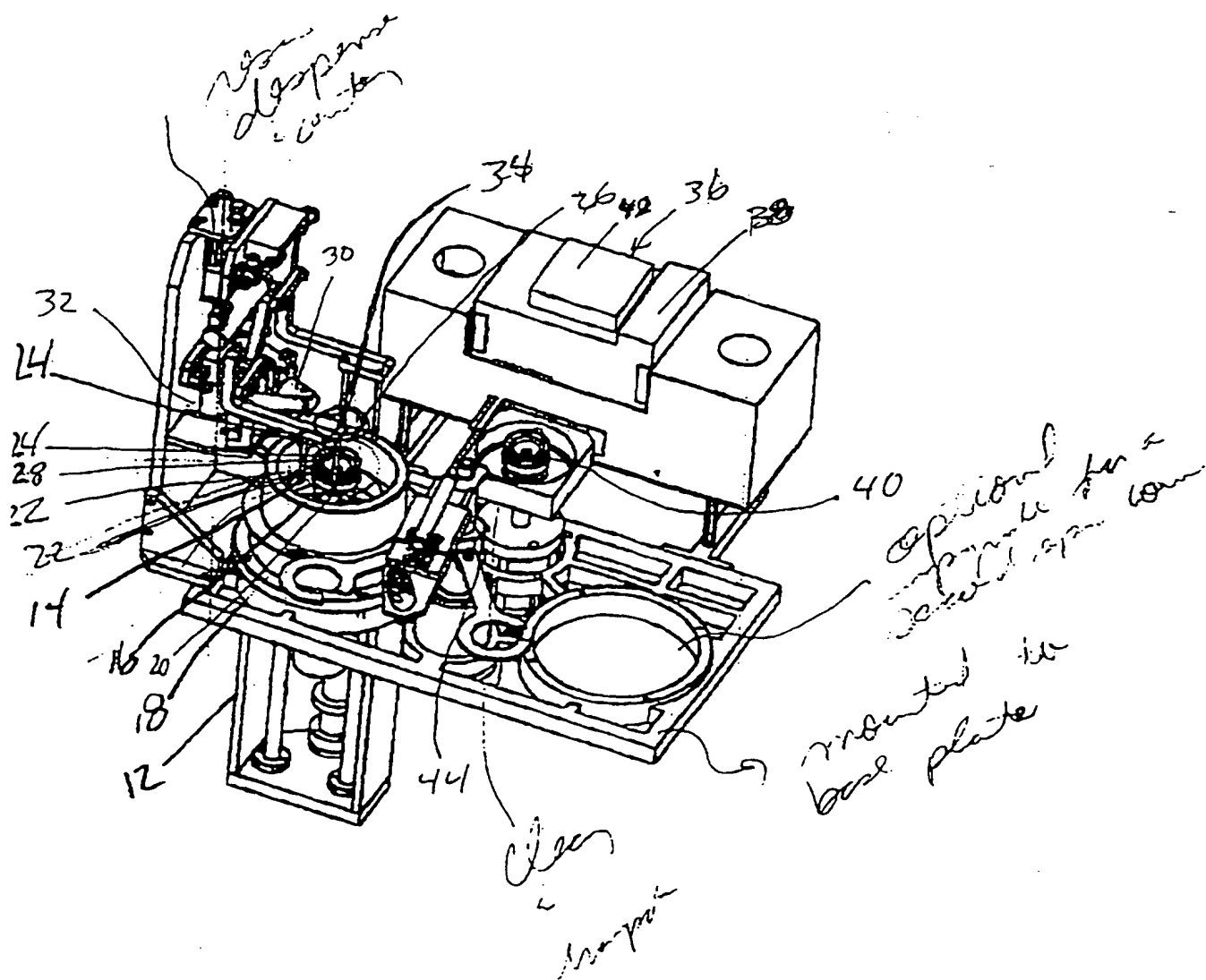


Fig 3
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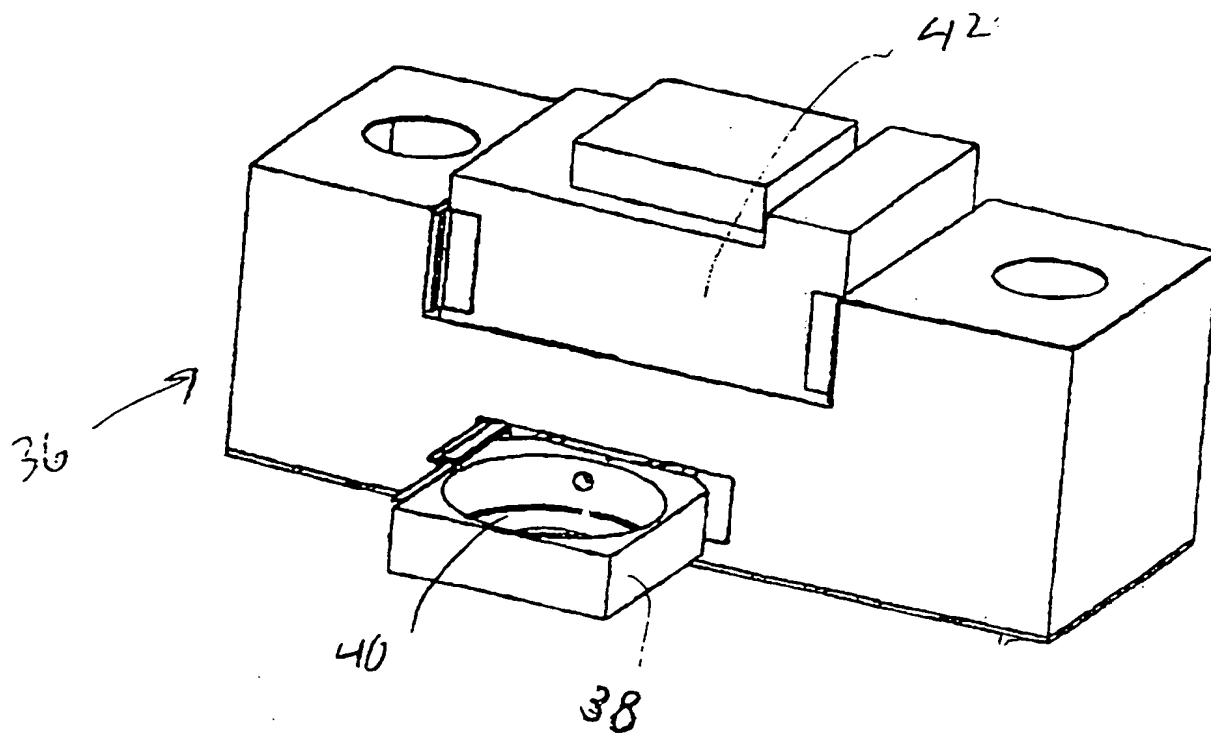


Fig 4

Curing station

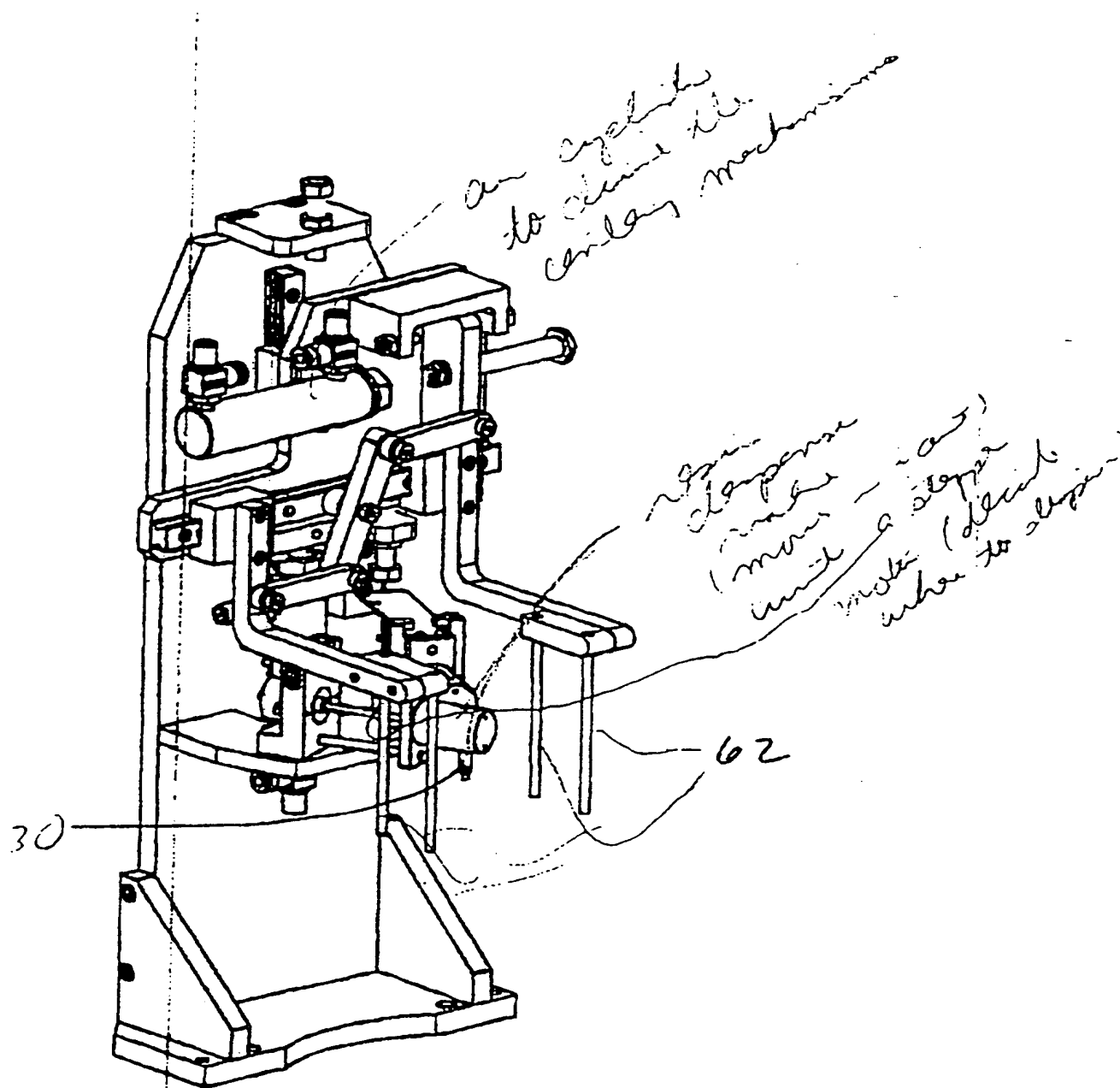
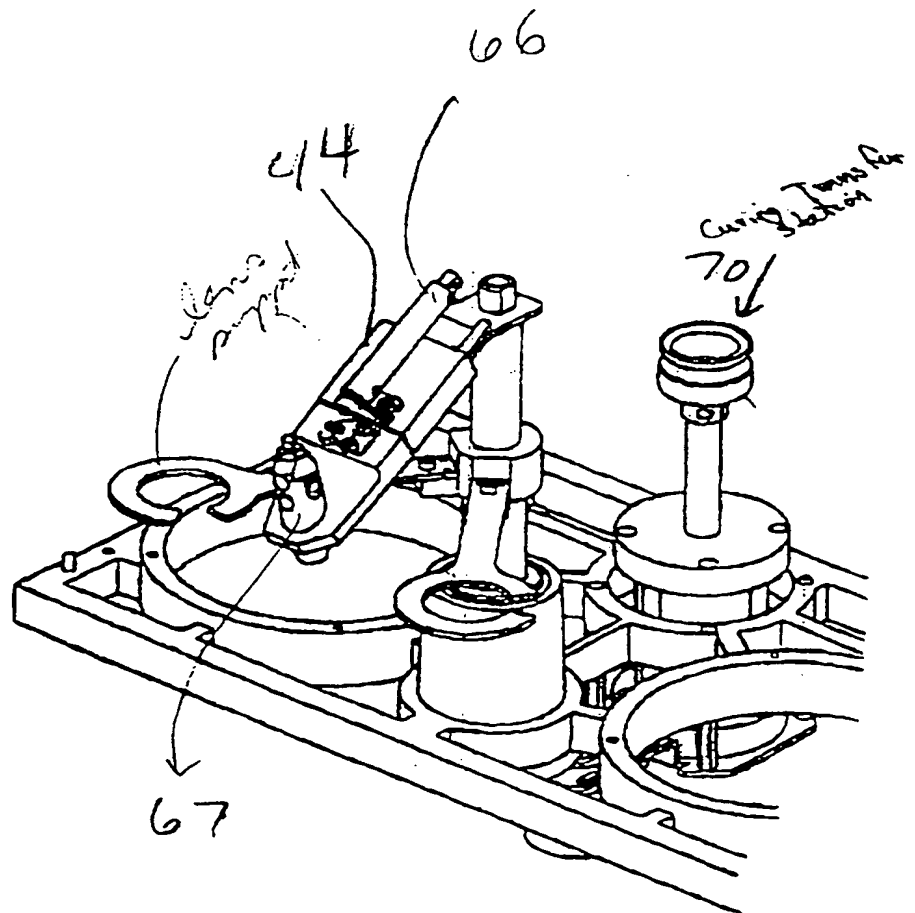


Fig 5

Distance & Centring Mechanism



Spray Cleaning
 Low Transportation

Fig. 6

INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 97/16548

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 805D1/00 805D3/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 805D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 515 149 A (BMC IND INC) 25 November 1992 see the whole document ---	1, 15, 33, 36, 37
A	US 5 246 728 A (RODRIQUEZ JORGE M) 21 September 1993 see the whole document ---	1, 11, 12, 15, 33, 36, 37
A	US 4 447 468 A (KEABLE JOHN B) 8 May 1984 see the whole document ---	1, 15, 33, 36, 37
A	US 4 143 468 A (NOVOTNY JEROME L ET AL) 13 March 1979 see the whole document ---	7
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Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

* Special categories of cited documents:

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INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 97/16548

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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